Reference Point

Understanding methicillin resistance in staphylococci isolated from dogs with pyoderma

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I solation of MRSP from canine skin has become a common occurrence. The increased prevalence of MRSP in dogs in recent years1 has raised a number of questions about the diagnosis, treatment, and prevention of these infections. Concerns about transmission of methicillin-resistant staphylococci can impact interactions between humans and their pets and affect patient care in veterinary practices.1 Unfortunately, in some situations, owners have been advised to remove pets from their households or even euthanize them because of concerns regarding transmission of these organisms.2 For these reasons, it is important that veterinarians understand the difference between MRSA and MRSP and know how to interpret positive culture results for these organisms in samples collected from dogs. Understanding staphylococcal infections has become increasingly important and challenging in recent years. The purpose of this report is to describe recent discoveries and advancements in our understanding of staphylococcal infections, particularly MRSP infection, in dogs and to summarize the available information regarding potential zoonotic transmission of these agents.

Staphylococci of Importance in Human and Veterinary Patients

Staphylococci are gram-positive, facultative, anaerobic cocci and are indigenous flora of the skin and mucous membranes of healthy dogs.3 Staphylococci cause opportunistic infections characterized by exudative lesions with local tissue inflammation.3 Skin infections are the most common type of staphylococcal infection, although bacteremia and life-threatening systemic disease (eg, toxic shock syndrome) can occur.5 Microscopic examination of lesion exudates reveals cocci in clusters, pairs, or short chains and neutrophils.5

More than 50 species and subspecies of Staphylococcus have been described.6 Historically, the ability of staphylococci to clot plasma was considered predictive of virulence, and staphylococci with this capacity were described as coagulase positive.7 Previously, coagulase-positive staphylococci isolated from dogs were classified as either Staphylococcus aureus or Staphylococcus intermedius. In 2005, Staphylococcus isolates from dogs previously identified as S intermedius were reclassified as Staphylococcus pseudintermedius, a species in the S intermedius–related group, on the basis of growth characteristics and biochemical features.8 First described in 1999 and expanded in 2005, the S intermedius–related group consists of closely related coagulase-positive staphylococci that differ in their host specificity.10,11 The group includes S pseudintermedius, predominantly isolated from dogs; S intermedius, isolated from pigeons; and Staphylococcus delphini, which has been found in a variety of animals, including dolphins, mink, cattle, and horses.8,10,12

Subsequent to this reclassification, S pseudintermedius has been considered the predominant cause of superficial pyoderma as well as a leading cause of otitis and of opportunistic infections at surgical sites in dogs.13–19 Two studies20,21 demonstrated that Staphylococcus schleiferi subsp schleiferi, which is coagulase negative, is also frequently isolated from dogs with skin disease. Although S aureus is a leading cause of infections in humans, it is less commonly isolated from dogs than is S pseudintermedius.14,19,22 S pseudintermedius can be readily cultured from samples collected from the nose, oral cavity, intestinal tract, urogenital tract, groin, and perineal regions of healthy dogs.22 In healthy dogs, reported frequencies for recovery of the organism were 8 of 69 (12%),22 54 of 150 (36%),23 and 6 of 43 (14%)24 from the nares and 14 of 69 (20%),22 27 of 74 (36%),23 and 14 of 43 (33%)24 from the anal mucosa. Additionally, S pseudintermedius is cultured more frequently from swabs of the rostral nares and anal mucosa of dogs that live in multidog households than from dogs that do not; this may reflect normal

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canine social behavior, such as sniffing the perianal region, which could facilitate transfer of staphylococci between animals. 53

Methicillin Resistance

Antimicrobial resistance in staphylococci—Historically, infections with staphylococci were associated with high morbidity and mortality rates in humans. 5 With the discovery of penicillin, this has changed. Penicillin and other β-lactam antimicrobials act by binding to and inhibiting the transpeptidase required for crosslinking of peptidoglycan in bacterial cell walls. 25 With β-lactam drug treatment, the peptidoglycan layer weakens and the bacteria are killed by increased osmotic pressure and cell rupture. 25 Some staphylococci produce a β-lactamase enzyme that destroys the β-lactam ring of penicillins and related antimicrobials, rendering them ineffective. 25, 27, 28 Methicillin was developed as a β-lactamase–resistant antimicrobial. Within a year after the introduction of methicillin in 1960, the first MRSA strains were identified. 26 Methicillin was quickly discarded as a therapeutic drug because of adverse effects; however, β-lactam–resistant staphylococci are still referred to as methicillin-resistant. 27 Methicillin-resistant staphylococci are resistant to all β-lactam antimicrobials including cephalosporins, penicillins, and amoxicillin-clavulanate combinations. 28 Many MRSP isolates are resistant not only to β-lactam drugs but also to 1 or more macrolides, lincosamides, trimethoprim-sulfonamide combinations, or fluoroquinolones. 21, 28 Chloramphenicol, tetracyclines, aminoglycosides, and rifampin remain drugs to consider for treatment of MRSP infection; however, culture and susceptibility testing should always be performed to evaluate susceptibility to these drugs. 25

Methicillin resistance genes—Penicillin binding protein 2a is a transpeptidase that has a low affinity for all β-lactam antimicrobials. 20–34 This protein is encoded by the mecA gene, and staphylococci that carry mecA are resistant to all β-lactam drugs. 29–31, 33 The evolutionary origin of mecA is unknown; however, the authors of a study 56 suggested that it may have originated within the genus of Staphylococcus from a mecA homolog identified in Staphylococcus sciuri, a coagulase-negative organism commonly isolated from animals.

The mecA gene is carried on a transmissible mobile DNA element called SCmec, 24 which can be transferred from one Staphylococcus isolate to another of the same or different species. 35 Thus, an isolate of S pseudintermedius that is susceptible to β-lactam drugs can become resistant to these agents through horizontal transfer of SCmec from a resistant isolate, creating a new strain of MRSP. 37 The element contains the mec gene complex, which consists of mecA, the genes that control expression of mecA, and unique site-specific recombinases called cassette chromosome recombinases. 22 Typing of SCmec is performed through analysis of the cassette chromosome recombinase gene complex and the mec gene complex. The International Working Group on the Staphylococcal Cassette Chromosome Elements has defined 11 SCmec types in S aureus to date. 38 At least 5 of these SCmec types (II-III, III, IV, V and VII-241) as well as 2 nontypeable cassettes have been identified in S pseudintermedius. 32 Once established, MRSP strains carrying specific SCmec types typically dominate in a geographic region. 37 Accordingly, it becomes possible to use SCmec typing in epidemiological studies to monitor for clonal spread of antimicrobial resistance and to assess zoonotic disease patterns. In addition, MRSP strains can be further grouped according to ST, which is determined through evaluation of alleles in 7 or more different loci to create an allelic profile for each isolate. 32 There is still limited information available regarding the population genetics of MRSP, but in North America, strain ST68 with SCmec V has been commonly isolated, whereas in Europe, strain ST71 with SCmec II-III has dominated. 30, 32, 37 There has been some debate about whether MRSP with SCmec II-III or SCmec III is the primary type found in Europe. 32, 33, 38 The apparent differences among studies may be related to differences among typing methodologies. 33, 40

Identification of methicillin-resistant staphylococci—Methicillin-resistant staphylococci are identified through detection of mecA by use of DNA-based tests such as PCR assays, antibody-based agglutination tests to detect penicillin binding protein 2a, or in vitro antimicrobial susceptibility testing. 41–43 Antimicrobial susceptibility testing includes assessment of resistance to oxacillin by means of disk diffusion or MIC testing. 42, 44 Evaluation of cefoxitin resistance is also used as a test for methicillin resistance in S aureus and coagulase-negative staphylococci but is less reliable for testing of S pseudintermedius; consequently, it is important that oxacillin, not cefoxitin, be used for identification of MRSP through antimicrobial susceptibility testing. 42, 45 Studies 42, 45 revealed that the 2004 Clinical and Laboratory Standards Institute oxacillin disk diffusion and MIC breakpoints of ≤ 17 mm and ≥ 0.5 µg/mL, respectively, predicted mecA-mediated methicillin resistance in S pseudintermedius better (ie, with fewer false susceptible results) than did the criteria established in 2008. The current Clinical and Laboratory Standards Institute standard 46 released in July 2013 reestablishes the 2004 breakpoints.

Pyoderma in Dogs

Classification and diagnosis—Pyoderma is one of the most common skin diseases in dogs and is defined as a pyogenic infection of the skin. When lesions are present, they are typically found on the ventral aspects of the abdomen and trunk, groin, muzzle, interdigital regions, and axilla. 13, 47 Superficial pyoderma is characterized by erythema of the skin with follicular or non-follicular papules and vesiculopustules that give rise to yellowish exudates or crusts. 14, 48 Superficial pyoderma may progress to a deeper form of disease that affects structures below the epithelium. With deep pyoderma, the predominant lesions often manifest as erythematous, exudative, alopecic nodules; draining tracts; and surrounding friable skin with surface ulcers. 49 Importantly, superficial and deep pyoderma often develop secondary to underlying disease processes. These can include allergic skin diseases, endocrinopathies, ectoparasitism, cornification defects, adverse drug reactions, foreign bodies, and neoplasia. 50, 51 In these situ-
ations, it is important not only to treat the bacterial infection but also to properly diagnose and treat the inciting cause of secondary pyoderma.\textsuperscript{30} Management of the bacterial infection consists of topical or systemic treatments or combinations of these.\textsuperscript{32} Pyoderma caused by methicillin-resistant staphylococci is clinically indistinguishable from that caused by methicillin-susceptible strains.\textsuperscript{36} However, pyoderma in dogs with methicillin-resistant staphylococcal infection can manifest as visible lesions 2 to 3 weeks after the initiation of empirical treatment, with bacteria detected on repeated cytologic examination. When empirical treatment fails, culture and antimicrobial susceptibility testing of samples is essential for choosing an appropriate alternate antimicrobial.\textsuperscript{3,22} Although MRSP is not more virulent than methicillin-susceptible \textit{S pseudintermedius} and the outcomes following appropriate treatment can be the same, proper antimicrobial selection is essential for success.\textsuperscript{47} Further, when an animal with a prior history of infection with methicillin-resistant staphylococci develops a subsequent infection or another pet in the same household develops an infection, a sample should always be collected for culture and susceptibility testing rather than initiating empirical treatment.\textsuperscript{32}

Careful collection of material is essential when obtaining samples for culture from the skin. Aspiration of material from an intact pustule is preferred; however, in dogs with superficial pyoderma, pustules are frequently transient, leaving circular, often alopecic skin lesions with exfoliative borders (commonly referred to as epidermal collarettes) on the skin.\textsuperscript{53} Results of some studies\textsuperscript{53,54} have indicated that epidermal collarettes are a feature of superficial pyoderma in dogs. In 1 study,\textsuperscript{55} bacteriologic culture of \textit{S pseudintermedius} from epidermal collarette swabs was successful for 18 of 22 dogs with superficial pyoderma, with 81.8% sensitivity and 100% specificity. Biopsy of the skin can also be performed to obtain sufficient tissue samples for diagnostic testing, particularly in cases of deep pyoderma when bacteria have infiltrated the underlying dermis.\textsuperscript{53}

\textbf{Treatment}—First-time cases of canine pyoderma are typically treated empirically, on the basis of the clinician’s experience, without culture and susceptibility testing.\textsuperscript{56} Antiseptic shampoos that contain benzoyl peroxide, chlorhexidine, ethyl lactate, triclosan, or salicylic acid are commonly used for treatment of superficial pyoderma in dogs.\textsuperscript{57} Investigators in 1 study\textsuperscript{58} found that use of topical treatments alone resulted in clinical resolution of staphylococcal pyoderma in 17 of 26 cases, with clinical improvement in 4 of the remaining cases. These treatments are often prescribed when large areas of the body are affected or when haired skin is involved.\textsuperscript{58} A full description of effective topical treatments for staphylococcal pyoderma can be found elsewhere.\textsuperscript{58} Topical products can be used alone or in conjunction with systemic antimicrobial administration.\textsuperscript{59} Although topical treatments offer some advantages over systemic treatment, such as higher local antimicrobial concentrations, these may not always be adequate to achieve clinical resolution of pyoderma.\textsuperscript{60}

For empirical systemic treatment of pyoderma in dogs, amoxicillin-clavulanic acid or first-generation cephalosporins (eg, cephalaxin) are the drugs most commonly selected.\textsuperscript{59} Clindamycin has been recommended as an appropriate alternative choice on the basis of its favorable safety profile, clinical efficacy, and distribution into the skin.\textsuperscript{52,57} Cefovecin and cefpodoxime proxetil are third-generation cephalosporins that are convenient for use in dogs because they do not require frequent administration. However, these drugs are only recommended as first-line agents in situations where owner compliance is a concern, because they have the potential to select for both methicillin-resistant staphylococci and extended spectrum β-lactamase producing organisms.\textsuperscript{59} Although effective against many staphylococcal isolates, trimethoprim-sulfonamide combinations should be avoided for long-term use because of potential adverse effects such as keratoconjunctivitis sicca, blood dyscrasias, and hypothyroidism.\textsuperscript{59} In dogs with recurrent infection, a sample should be collected from a lesion for culture and susceptibility testing to guide proper drug selection.\textsuperscript{32}

Treatment for superficial pyoderma should be continued for 1 week past the resolution of clinical signs; this would typically require ≥ 3 weeks of treatment.\textsuperscript{59} Because of the increased depth and severity of lesions in dogs with deep pyoderma, a minimum treatment period of 4 weeks should be considered, with an endpoint of 2 weeks past the resolution of clinical signs.\textsuperscript{59} It is important that the patient be reexamined and that cytologic evaluation of aspirates and impression smears be repeated during the course of treatment to assess the patient’s response. Otherwise, if infection is detected after the end of the treatment period, it becomes difficult to determine whether the patient has been reinfected or the original treatment protocol has failed because of an incorrect antimicrobial choice or premature discontinuation of an appropriate drug regimen. Overall prognosis is good if the underlying cause can be identified and corrected or well-controlled to prevent recurrent infection.\textsuperscript{50} As previously mentioned, conditions that predispose dogs to pyoderma can hinder successful management of the infection if not properly addressed.\textsuperscript{32}

When infection with methicillin-resistant staphylococci has been identified, proper drug choice is essential. Topical treatments can be provided but should only be used as adjuncts to systemic antimicrobial treatment administered at the correct dosage on the basis of the dog’s current body weight and given for the prescribed period.\textsuperscript{32} Methicillin-resistant \textit{Staphylococcus} infection should not be treated with β-lactams, cephalosporins, or amoxicillin-clavulanic acid because these are ineffective against the bacteria.\textsuperscript{3,28,32} Fluoroquinolones are often a poor choice for long-term treatment because susceptible strains quickly develop resistance to this class of drugs.\textsuperscript{21,29,62,63} Development of resistance against trimethoprim-sulfonamide combinations and clindamycin has also been reported.\textsuperscript{59} In addition, it is important to note that inducible clindamycin resistance can occur, wherein an isolate appears susceptible in vitro, but resistance is induced during treatment of the patient, resulting in treatment failure.\textsuperscript{59} Specialized laboratory testing can detect inducible clindamycin resistance when an isolate is susceptible to clindamycin but resistant to erythromycin.\textsuperscript{64}
Currently, aminoglycosides (eg, gentamicin or amikacin), tetracyclines (eg, doxycycline or minocycline), rifampin, and chloramphenicol are considered therapeutic choices for treatment of methicillin-resistant Staphylococcus with multiple-drug resistance only if MIC testing confirms susceptibility to these agents. All drug choices require evaluation of patient factors that would contraindicate selection of a drug. In particular, well-known, serious adverse effects may occur with each of these drugs. Aminoglycosides can have nephrotoxic effects. Doxycycline has been reported to rarely cause renal or hepatic injury and esophageal lesions, especially in cats. The most common adverse effect of rifampin is hepatotoxicity, but gastrointestinal disturbances and orange-red discoloration of the urine, tears, and sclera have also been noted. In dogs, chloramphenicol can cause gastrointestinal upset, weight loss and uncommonly results in liver toxicosis, bone marrow suppression, weakness, and neurologic tremors. Additionally, this drug can have serious adverse effects, such as aplastic anemia and bone marrow suppression in humans, and therefore requires special handling. Chloramphenicol can also have adverse interactions with several classes of drugs because it interferes with the cytochrome P450 pathway and thus decreases clearance of other drugs metabolized by this pathway.

Additional factors specific to treatment of methicillin-resistant staphylococcal infection should also be considered when choosing an appropriate antimicrobial agent. Rifampin should not be used alone because resistance develops rapidly under these circumstances. In a 2011 study of dogs with MRSP infection, resistance to rifampin emerged rapidly, even when the drug was used in combination with other antimicrobials. Chloramphenicol has been an important agent for treatment of MRSP infection in dogs because historically, MRSP has been susceptible to this drug. However, in Europe, chloramphenicol resistance in MRSP has become widespread. This is of particular concern because MRSP has only been reported since 2007 in Europe, and the finding suggests that chloramphenicol resistance has developed rapidly. Resistance to this drug occurs through inactivation by a type A chloramphenicol acetyltransferase, which can be transferred among bacterial strains. Finally, despite the potential efficacy of vancomycin and linezolid against methicillin-resistant staphylococci, these drugs should not be used in veterinary medicine because of their importance for treating human MRSA infections.

Zoonotic Potential of MRSA and MRSP

Several species, including humans, dogs, cats, horses, pigs, poultry, and some exotic animals, can serve as carriers for and as sources of infection with various strains of Staphylococcus. There are several misconceptions among clients and veterinarians regarding the implications of infection with MRSA or MRSP in dogs. It is also important to understand the difference between colonization with (ie, carriage of) an organism and infection. Discriminating between MRSA and MRSP and understanding the applicable terminology are important for diagnostic reasons, for establishing the correct treatment protocol, and for protecting public health.

MRSA—Staphylococcus aureus is a leading cause of nosocomial infection in humans and is found in approximately 30% of healthy individuals in the United States. The US CDC defines a person as being colonized or having bacterial carriage when the bacteria is present without causing disease in the individual. This is in contrast to infection, in which an individual has clinical signs of disease. Fortunately, only a small proportion (<2%) of healthy or asymptomatic individuals in the general population of the United States carry MRSA. Colonization can be transient or can become persistent, particularly in cases of repeated exposure. A person who lives in close contact with an MRSA-infected person can become persistently colonized with the same MRSA strain for months to years, and during this time, they can serve as a source of secondary transmission to other individuals. The degree of risk appears to be related to closeness of exposure because the risk of colonization for a spouse or child of a patient with MRSA is almost 7 times as great as that for a casual associate such as a friend or roommate.

Staphylococcus aureus colonization in dogs is possible, but it is not common because the organism is not normally a component of the indigenous bacterial flora of dogs. The reported prevalence of S aureus infection in dogs has ranged from 2 of 24 (8.3%) to 6 of 59 (10%), whereas that of S aureus carriage in healthy dogs has ranged from 2 of 43 (4.7%) to 6 of 50 (12%). Prevalence of MRSA is lower, with the organism isolated from 1 of 59 (1.7%) infected dogs in 1 study and rates of carriage in healthy dogs as low as 0% found in studies that evaluated 50 dogs and 200 dogs. Specific host and environmental conditions must be met for a dog to be exposed, become colonized, and serve as a potential reservoir for the organism while remaining apparently healthy. It has been suggested that MRSA infection or colonization in dogs results from transmission of the organism by humans, to decrease the potential for transmission, veterinarians and veterinary staff should be educated about this occupational health risk and should consis-
MRSP—Staphylococcus pseudintermedius is the most commonly encountered Staphylococcus spp in the canine population and, unlike S aureus, is part of the indigenous bacterial flora in dogs. In a study in 2011 in which samples from the nares, pharyngeal region, and perineum of dogs were collected with swabs in the waiting room area of a small animal hospital, investigators identified factors potentially associated with recovery of MRSP from dogs, including antimicrobial or corticosteroid treatment within the 6 months prior to culture, previous hospitalization, and entering a veterinary facility within the 4 weeks prior to culture. Results of the same study revealed that 49 of 390 (12.6%) dogs treated with antimicrobials tested positive for MRSP, compared with 9 of 386 (2.3%) dogs that did not receive these drugs. This suggests that antimicrobial administration may potentially select for carriage of MRSP in dogs and supports the need for proper timing and selection of antimicrobial treatments.

Unlike S aureus, S pseudintermedius is not a commensal organism in humans. Although infection does occur in humans, it appears to be uncommon and is usually associated with zoonotic transmission from a canine host. Our current understanding is that the overall importance of S pseudintermedius as a zoonotic pathogen is less than that of MRSA. In humans, S intermedius (S pseudintermedius would have been identified as S intermedius prior to 2005) infection was described in a few hospitalized patients in 1997 with a low prevalence (2/3,397 [0.06%]). In a 2010 study that included several regions across the United States, the prevalence of MRSP carriage in veterinary dermatologists and their technical staff was found to be 9 of 171 (5.3%). This was slightly lower than the 16 of 258 (6.2%) carriage rate in healthy dogs in the same study. Investigators in another study showed that 6 of 13 (46%) owners of dogs with deep pyoderma carried antimicrobial-resistant strains of S pseudintermedius identical to those recovered from their own dogs; the strains recovered from each dog-owner pair were distinct among the different households. This raises concerns that horizontal transfer of resistance genes may occur between antimicrobial-resistant S pseudintermedius and pathogenic strains of staphylococci carried by humans. At present, S pseudintermedius rarely causes disease in humans, and the risk of transmission of MRSP from a pet to the owner should be evaluated on an individual basis.

Infection Control Measures

In-hospital practices—Treatment of patients infected with methicillin-resistant staphylococci must incorporate prevention of nosocomial and zoonotic transmission. Consistent attention to hand hygiene (eg, using gloves, washing hands with soap and water after touching a patient and the use of alcohol pouches to clean hands when water is not available) has been repeatedly shown to be a protective factor against transmission, because staphylococcal infections are often spread through direct skin contact. Several studies have shown that hospital personnel and equipment can serve as routes for transmission of infection. Investigators of a 2010 study found that 66 of 100 (66%) pens, 44 of 80 (55%) stethoscopes, 60 of 126 (47.6%) cell phones, and 37 of 130 (28.5%) white coats used by physicians in a human hospital were contaminated with various bacteria. Staphylococcus spp were most commonly found, comprising 122 of 436 (28.0%) isolates, and 9 (7.4%) of these were identified as MRSA.

Staphylococci can survive for long periods in the environment. One study showed that staphylococci were able to survive on a variety of fabric types and plastic materials in a human hospital, sometimes for >90 days. In a veterinary teaching hospital, evaluation of environmental surface samples via DNA sequencing and PCR assay revealed that various cages, the top surfaces of a CT scan stand, a stand in a cat ward, and floors of the intensive care unit and MRI room were contaminated with MRSP. Routine disinfection of hospital surfaces and equipment as well as the use of stringent hand hygiene practices are critical to prevent or minimize the spread of infection. Most disinfectants are effective when applied to clean surfaces, and some quaternary ammonium compounds have been shown to retain antimicrobial activity for up to 48 hours.

In addition to appropriate use of disinfectants and hand hygiene, the handling of infected patients should be limited to veterinary staff directly involved in their care to minimize the potential for transfer of organisms to other patients or staff members. Personal protective equipment should be worn to prevent contamination of clothing or body surfaces and transmission of bacteria to other patients or coworkers. This includes washable attire such as laboratory coats and disposable items such as gowns, gloves, or masks. Any patient with wounds should have those areas covered with a dressing to reduce environmental contamination, and soiled dressings should be disposed of properly. Proper treatment and containment of the infection are the ultimate goals. Ideally, every hospital should have a formal written manual that delineates infection control procedures and guidelines, and an individual staff member should be assigned the task of ensuring that the program is understood and followed.

Owner recommendations—It has been shown that MRSP and MRSA can be transferred among humans and pets in households. Dogs known to have MRSP infections should not be allowed to share a bed with their owners because this provides an opportunity for close contact and potential transfer of the organism. Similarly, humans with known MRSA infections should not allow a pet to lick their wounds or share their bed. Personal hygiene and environmental disinfection are vital in maintaining appropriate infection control in the home environment. Staphylococci can survive for days on fabric, vinyl, and plastic; and dust particles can preserve these organisms and also serve as source of contamination or infection. Cleaning and disinfection are appropriate measures for disrupting transmission and reinfection. However, the most important infection prevention measure is to consistently practice proper hand hygiene after handling a patient or contaminated material.
Conclusions

Because they are uniquely adapted commensal organisms, staphylococci are likely to remain a cause of opportunistic infection in humans and animals. Staphylococcal infections can range from simple skin infections and dermatologic disorders to severe bacteremias that can cause multiorgan failure and death.\(^4\,13\,24\)

For dogs with pyoderma, there are several key points that remain at the heart of successful treatment. Any underlying, predisposing conditions must be corrected or controlled to provide the best opportunity for clinical resolution. Because pyoderma caused by antimicrobial-susceptible staphylococci is clinically indistinguishable from that caused by antimicrobial-resistant strains,\(^46\) patients that receive empirical treatment must be re-evaluated during the treatment period to assess clinical response. When empirical treatment fails or infection reoccurs, culture and antimicrobial susceptibility testing of a sample should be performed to guide selection of an appropriate alternate antimicrobial drug. Finally, despite the potential efficacy of vancomycin and linezolid against methicillin-resistant staphylococci, these drugs should not be used in veterinary medicine because of their importance for treating human MRSA infections. Breaking the transmission cycle between humans and animals requires diligent hand hygiene and careful disinfection of the surfaces or materials on which staphylococci survive and proliferate.

Additional research is needed to improve our understanding of *S pseudintermedius* infection in dogs. Debate remains about whether there are differences between MRSA and MRSP infections in dogs with regard to severity of clinical signs and outcome. In general, it is thought that dogs are not preferred carriers of *S aureus* and infection or colonization of dogs by MRSA results from transmission from humans.\(^3\,30\,35\) It is also thought that humans are not preferred carriers of *S pseudintermedius*. Although this suggests that the potential for colonization or infection of the owner is generally low when a pet is identified as having an MRSP infection, this may not be the situation for immunocompromised owners,\(^17\,39\) and each case should be evaluated individually.

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